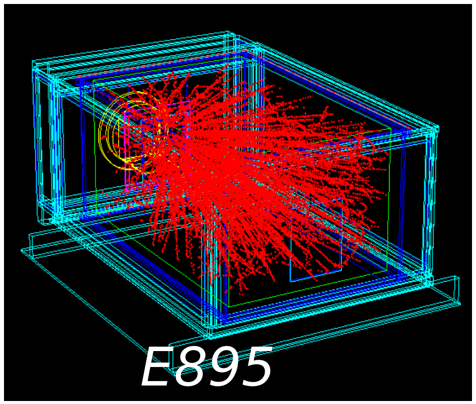
Furture of heavy ion collisions:
→ Fluctuations:
→ FT@LHC

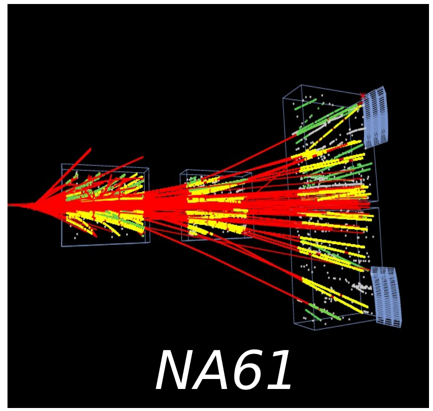
M.G., Frankfurt, Kielce,

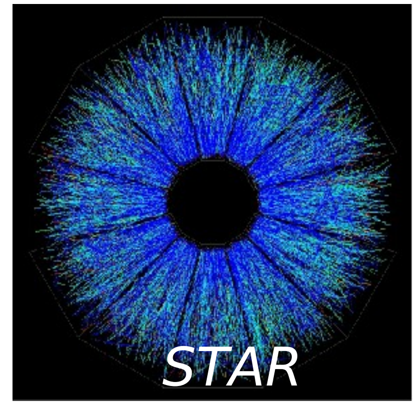
- Experimental status
- Why event-by-event fluctuations?
- Towards ideal detectors

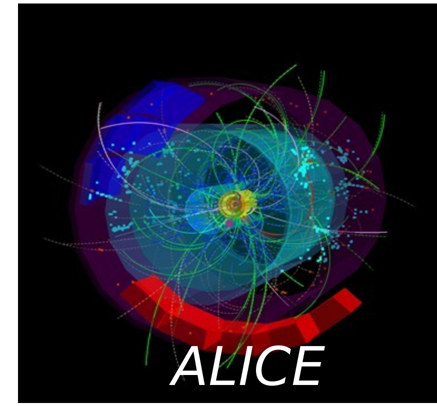
Experimental status

BNL AGS → CERN SPS → BNL RHIC → CERN LHC







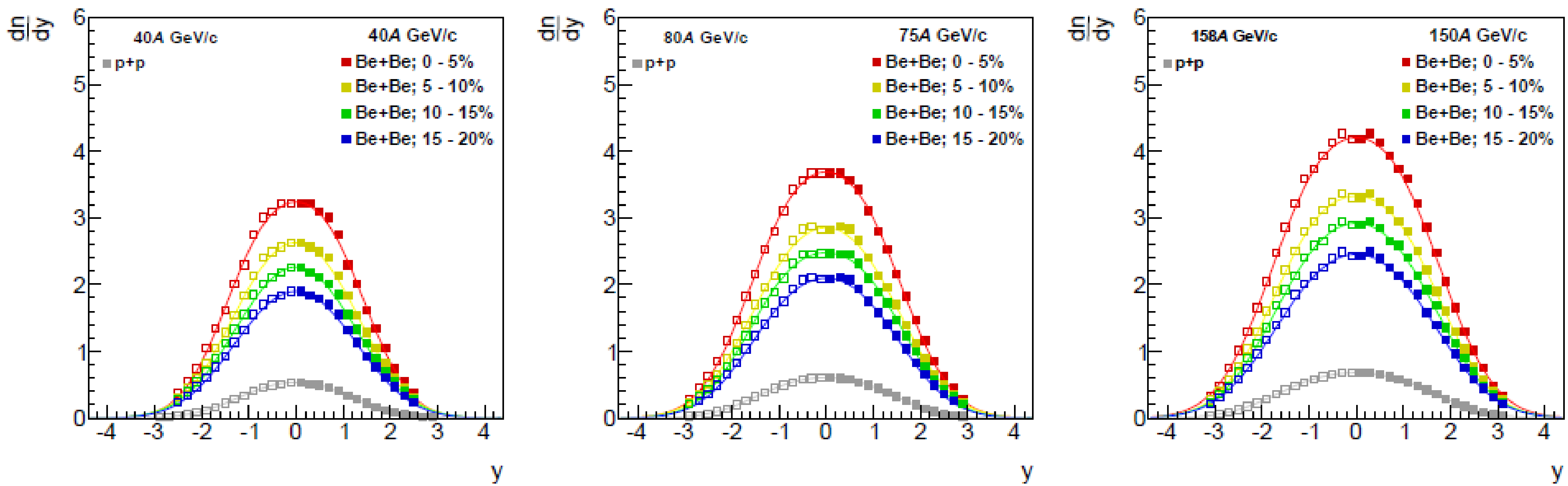


→ rich experimental data on single particle spectra
in Pb+Pb and p+p interactions
from several GeV to several TeV

→ but due to an incomplete acceptance of detectors
poor data on event-by-event fluctuations

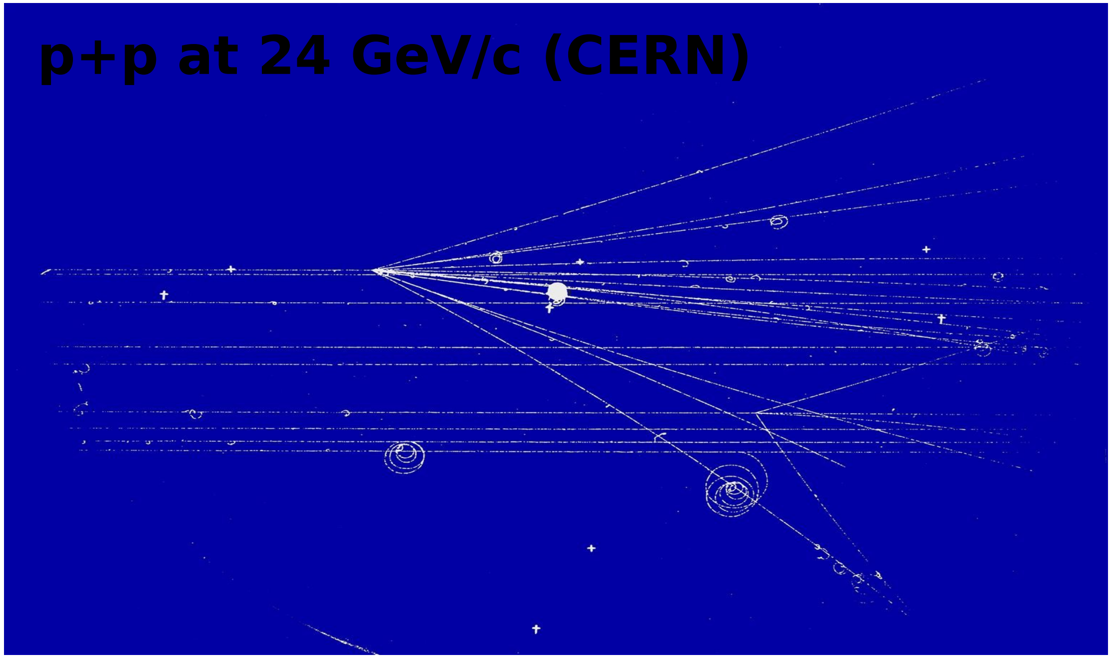
Single particle spectra are easy to measure as one can partly/fully correct for a limited acceptance using forward-backward and rotational symmetries which are obeyed by an “average” event

→ 4π detectors are not needed to measure single particle spectra in 4π

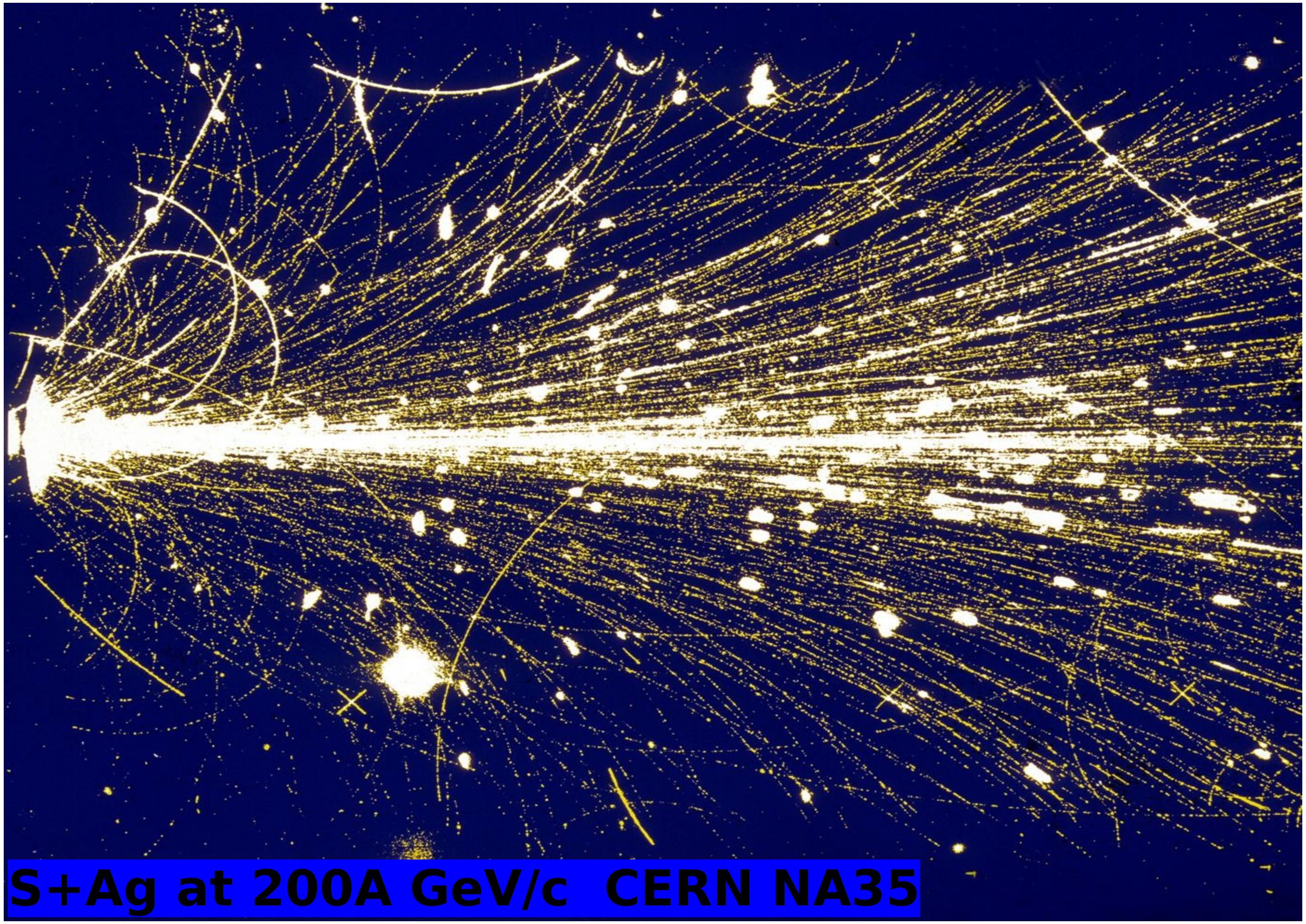


Event-by-event fluctuations are difficult to measure as one cannot correct for a limited acceptance using forward-backward and rotational symmetries (they are not obeyed by a single event)
→ a 4π detector is needed to perform measurements of fluctuations in 4π

Up to now almost the only data on event-by-event fluctuations in 4π are results on fluctuations of charged hadron multiplicity in p+p interactions. The measurements come form bubble and streamer chamber experiments performed many years ago.

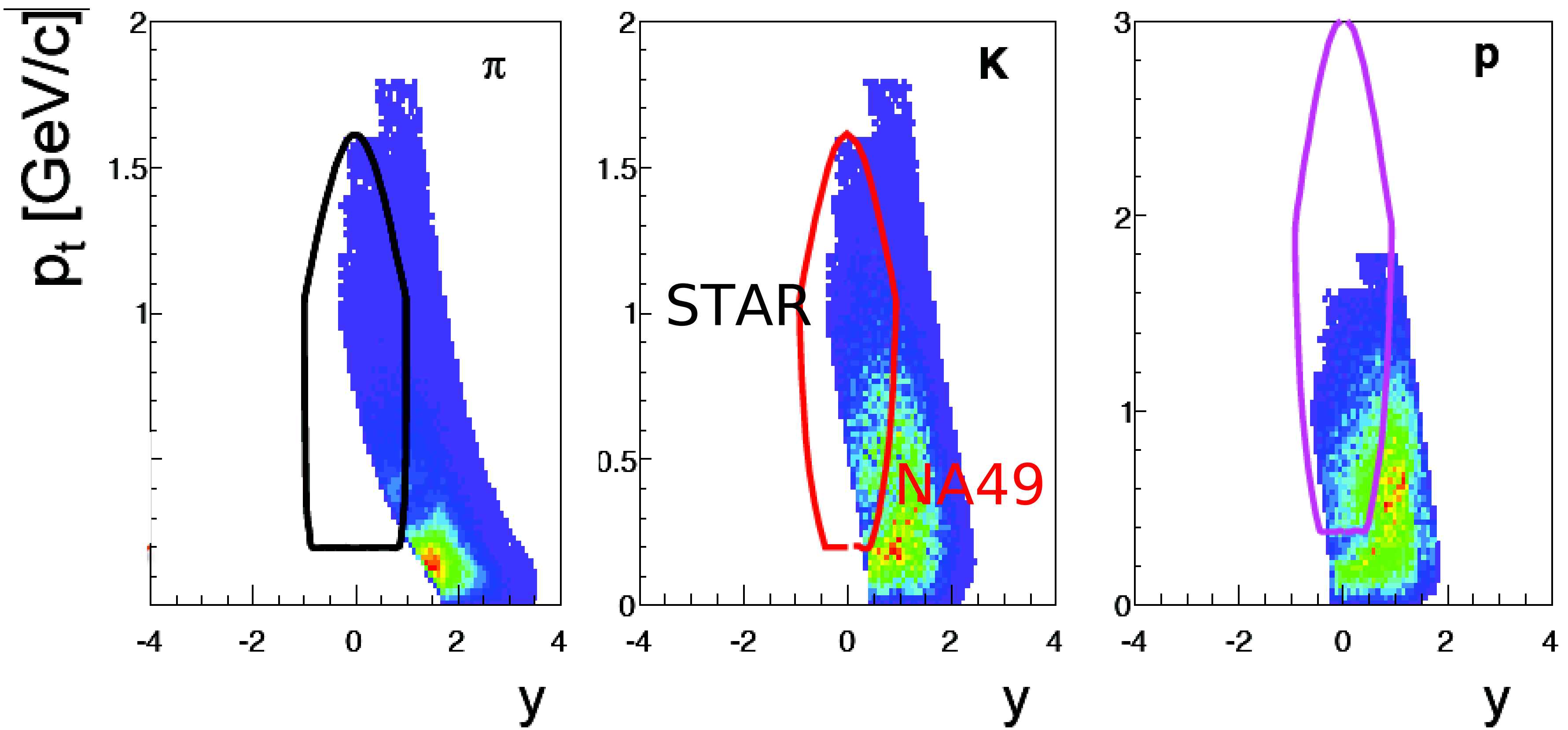


In the bubble and streamer chamber experiments events were read-out by projecting them onto a 2D film plane.
In A+A collisions at high energies track density is too high to use the 3D → 2D projection during the read-out.

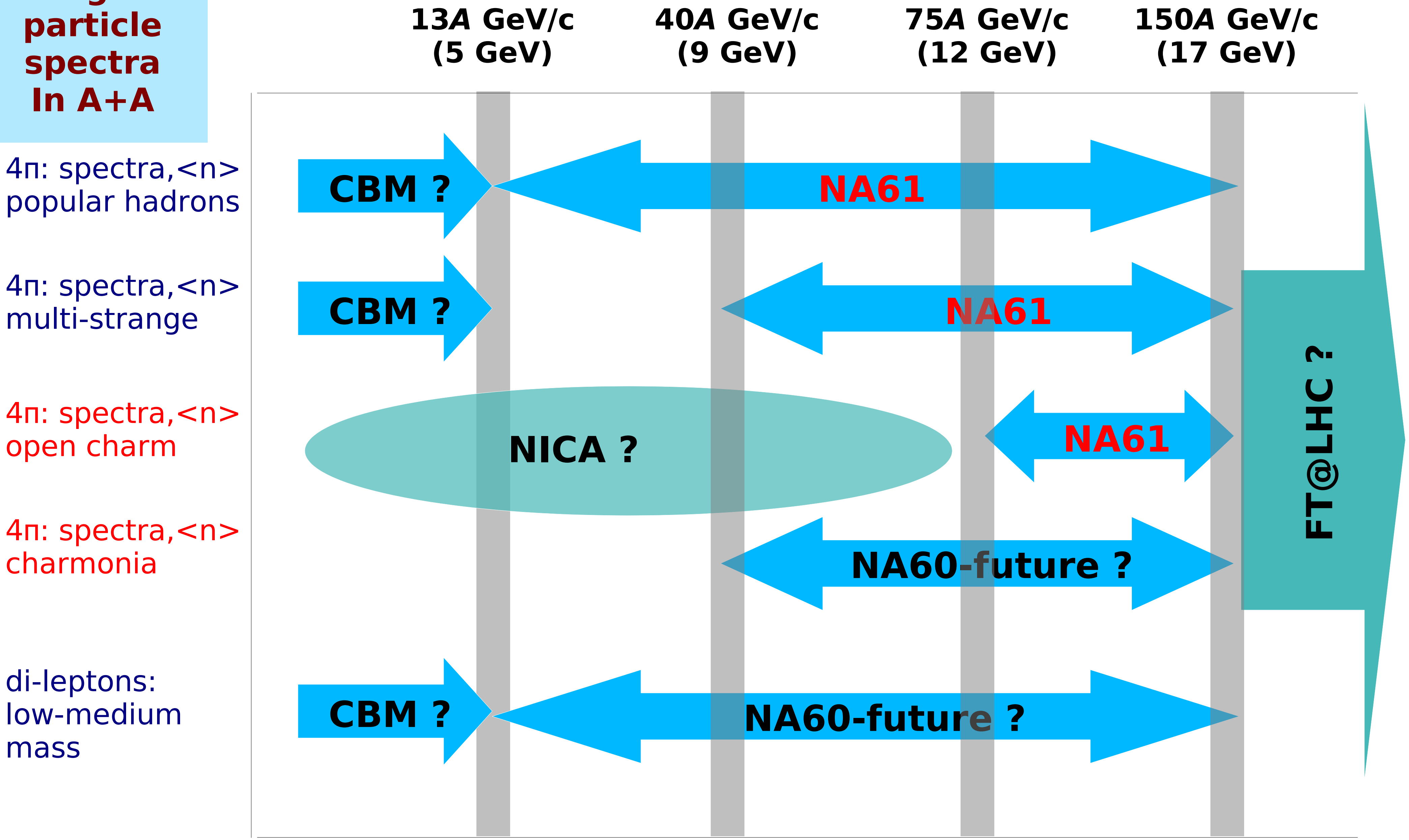


In order to overcome this problem modern experiments use Time Projection Chambers instead of bubble chambers. Moreover, they run in the collider mode at very high energies. The price is a limited or very limited acceptance and consequently poor data on event-by-event fluctuations.

An example: the NA49 and STAR acceptances for analysis of fluctuations of identified hadrons:



single particle spectra In A+A

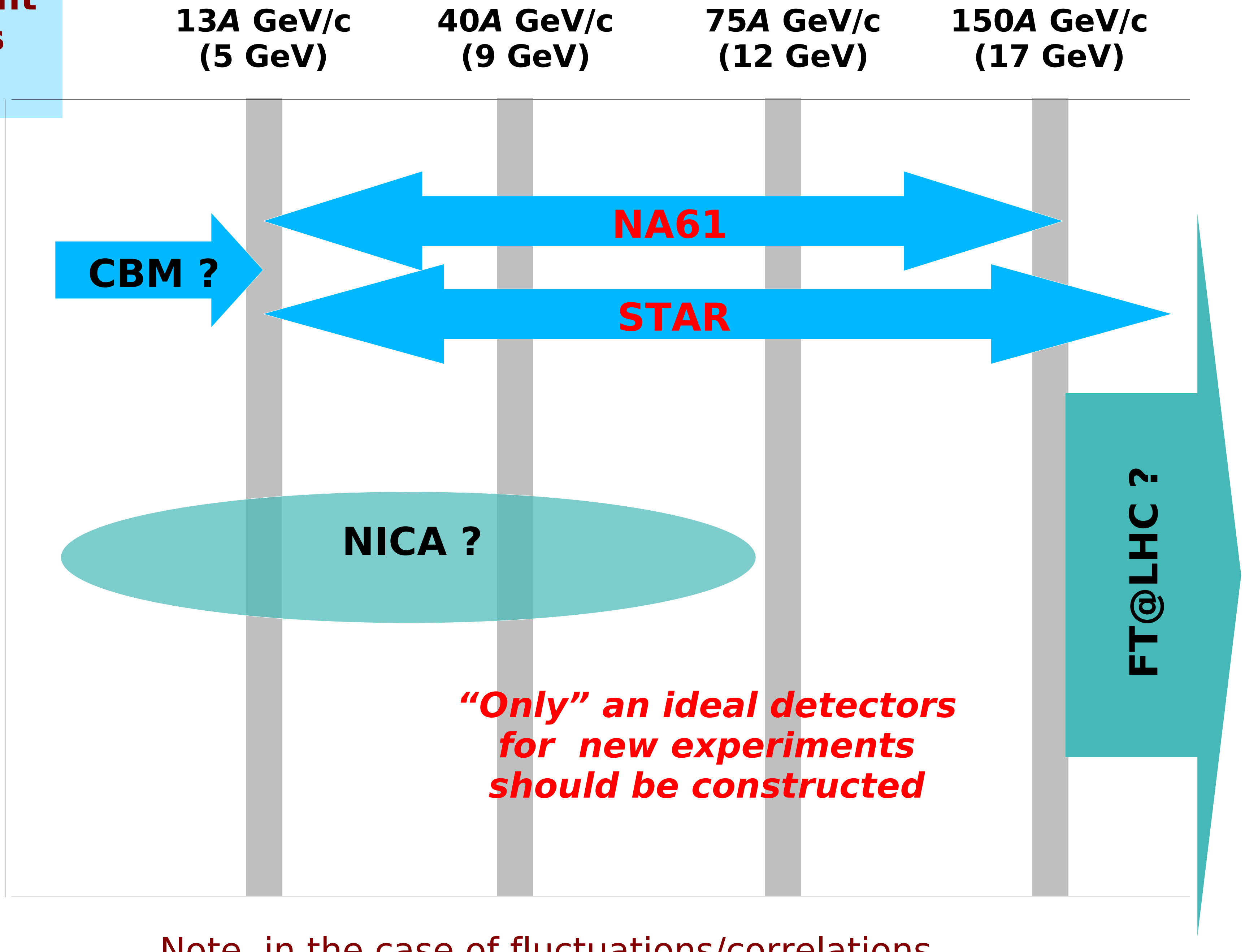


Note, in the case of single particle spectra one can partly/fully correct for a limited acceptance using forward-backward and rotational symmetries

event-by-event fluctuations in A+A

fluctuations
acc < (<<)50%

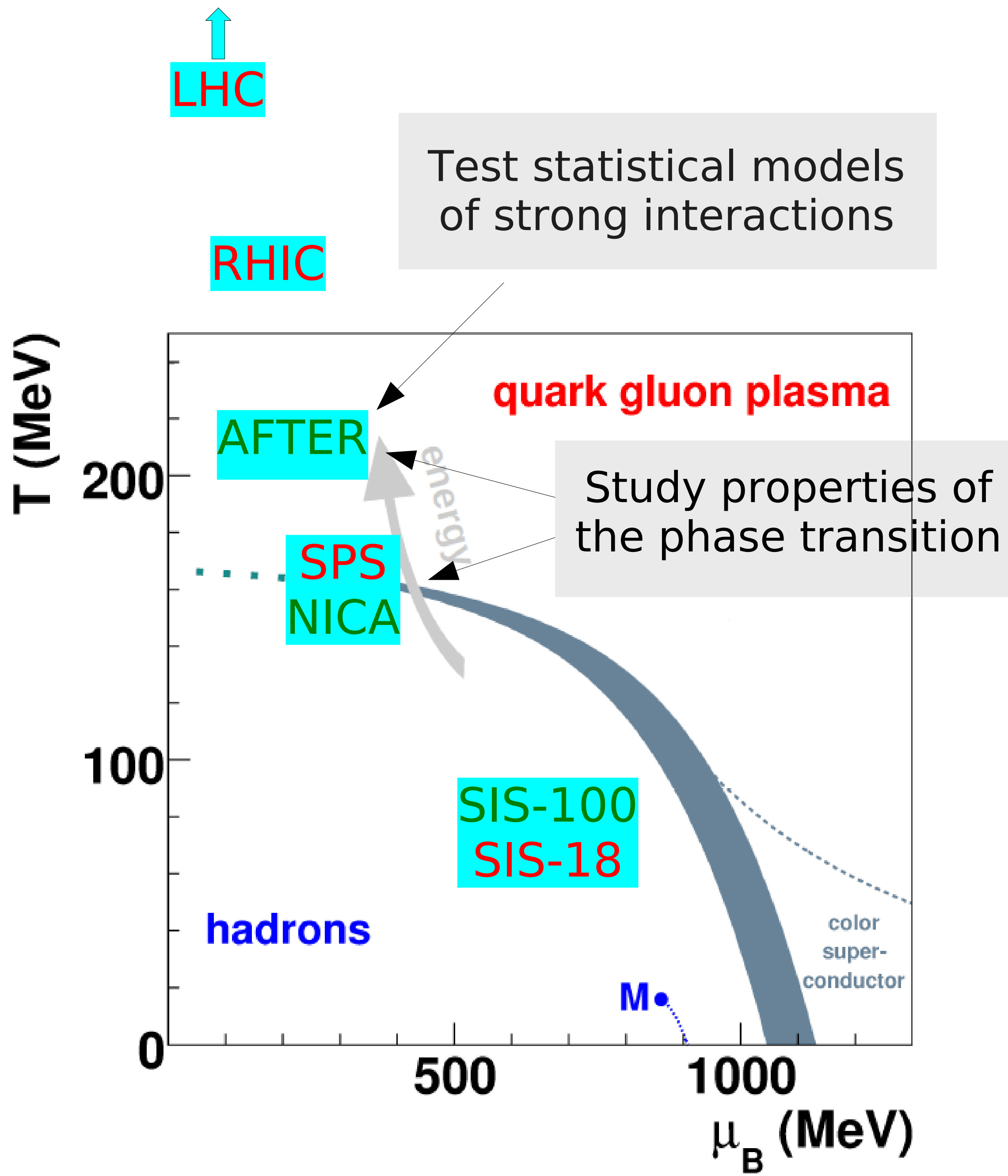
fluctuations
acc ≈ 100%



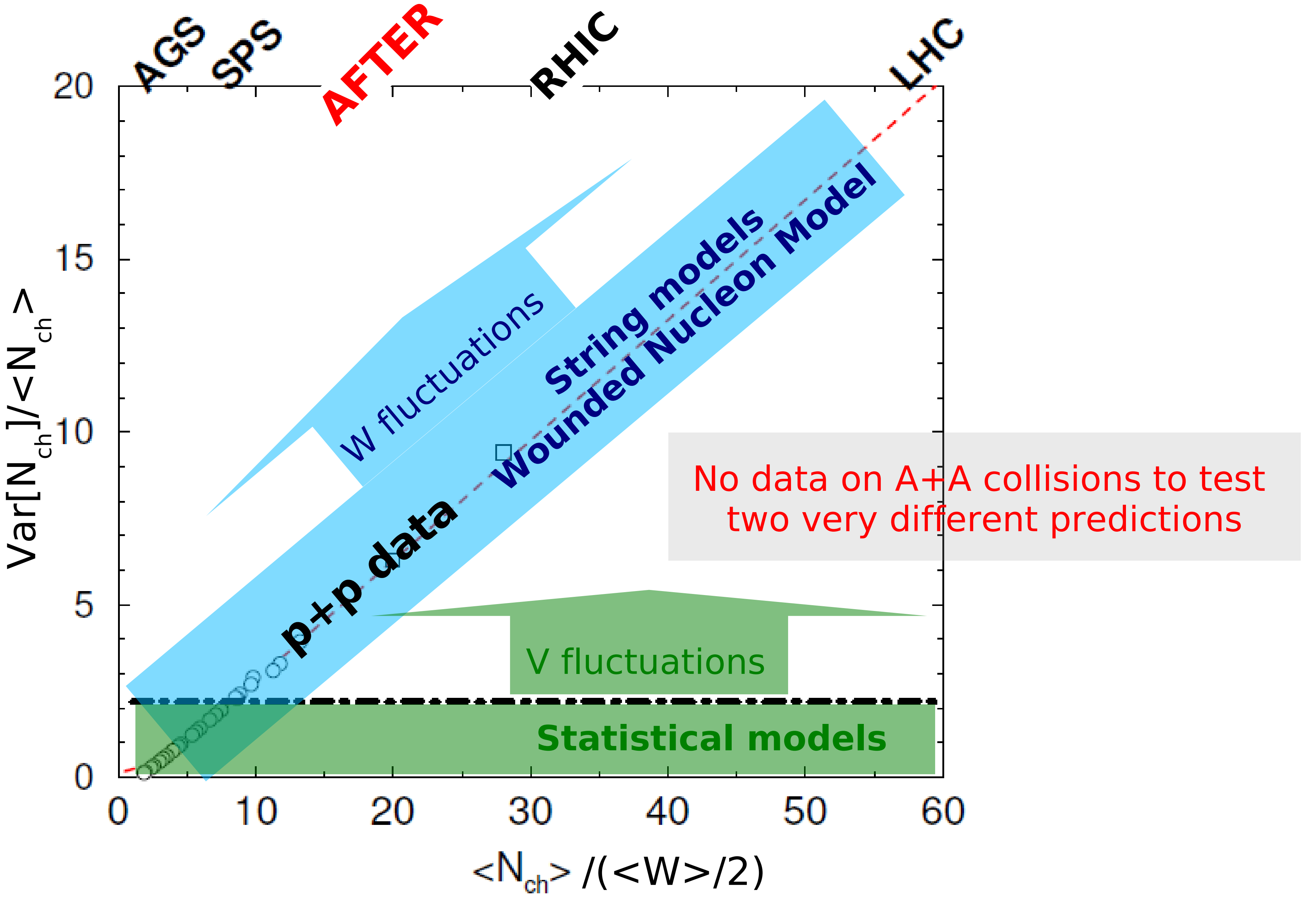
Note, in the case of fluctuations/correlations
One can not correct for a limited acceptance
using forward-backward and rotational symmetries

Why event-by-event fluctuations?

energy (GeV)	accelerator/exps in operations accelerator/exps In plans
~1	SIS-18/HADES SIS-100/HADES-CBM
~10	NICA/MPD SPS/NA61 AFTER@LHC
~100	RHIC/STAR,PHENIX
~1000	LHC/ALICE,ATLAS,CMS

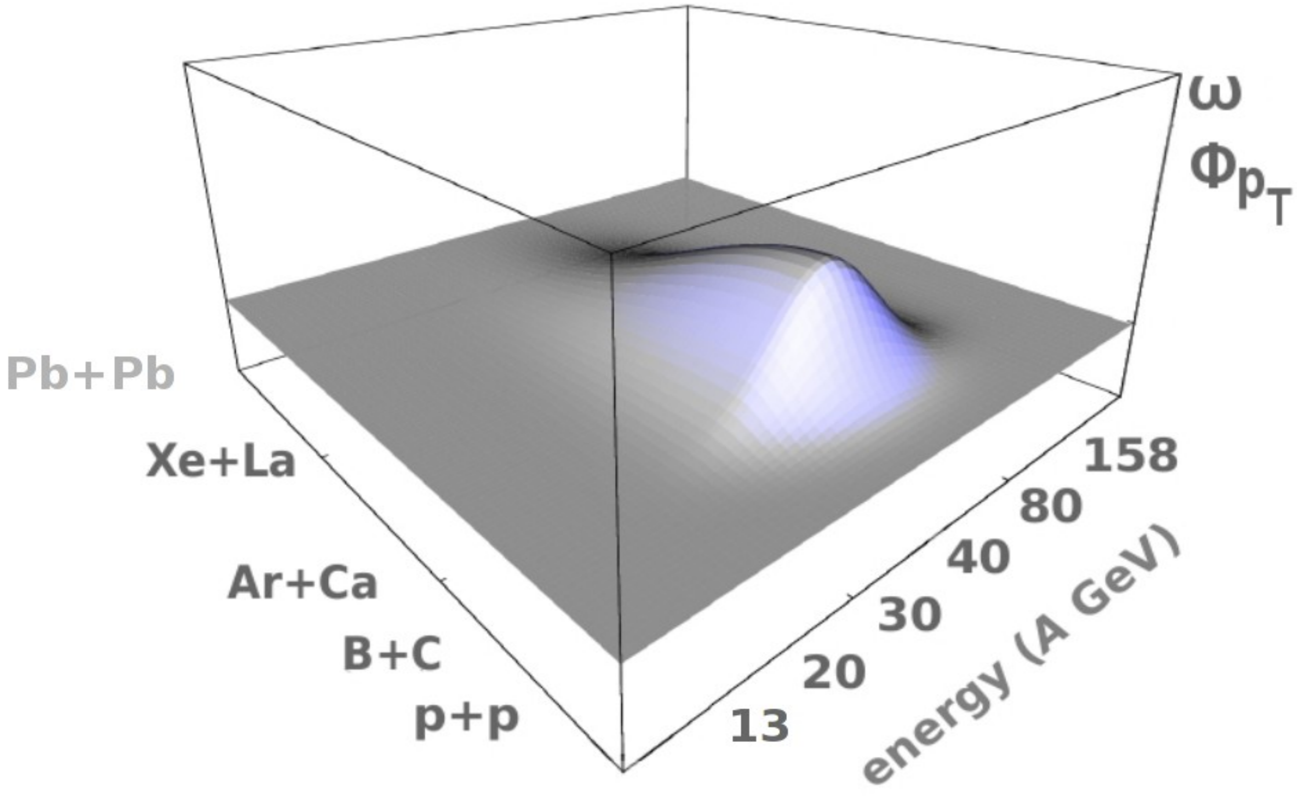


At higher energies (> 20 GeV, AFTER): important test: statistical vs dynamical models of strong interactions



STAR: too small acceptance, difficult to fix V fluctuations
NA61: too low energy

At lower energies (8-70 GeV SPS/AFTER): search for the critical point of strongly interacting matter



Enhanced fluctuations are the main signal of the critical point but the resolution of the current experiments (NA61, STAR) significantly limited by the limited acceptance. Moreove, in collider experiments (e.g. STAR) difficult to fix V fluctuations

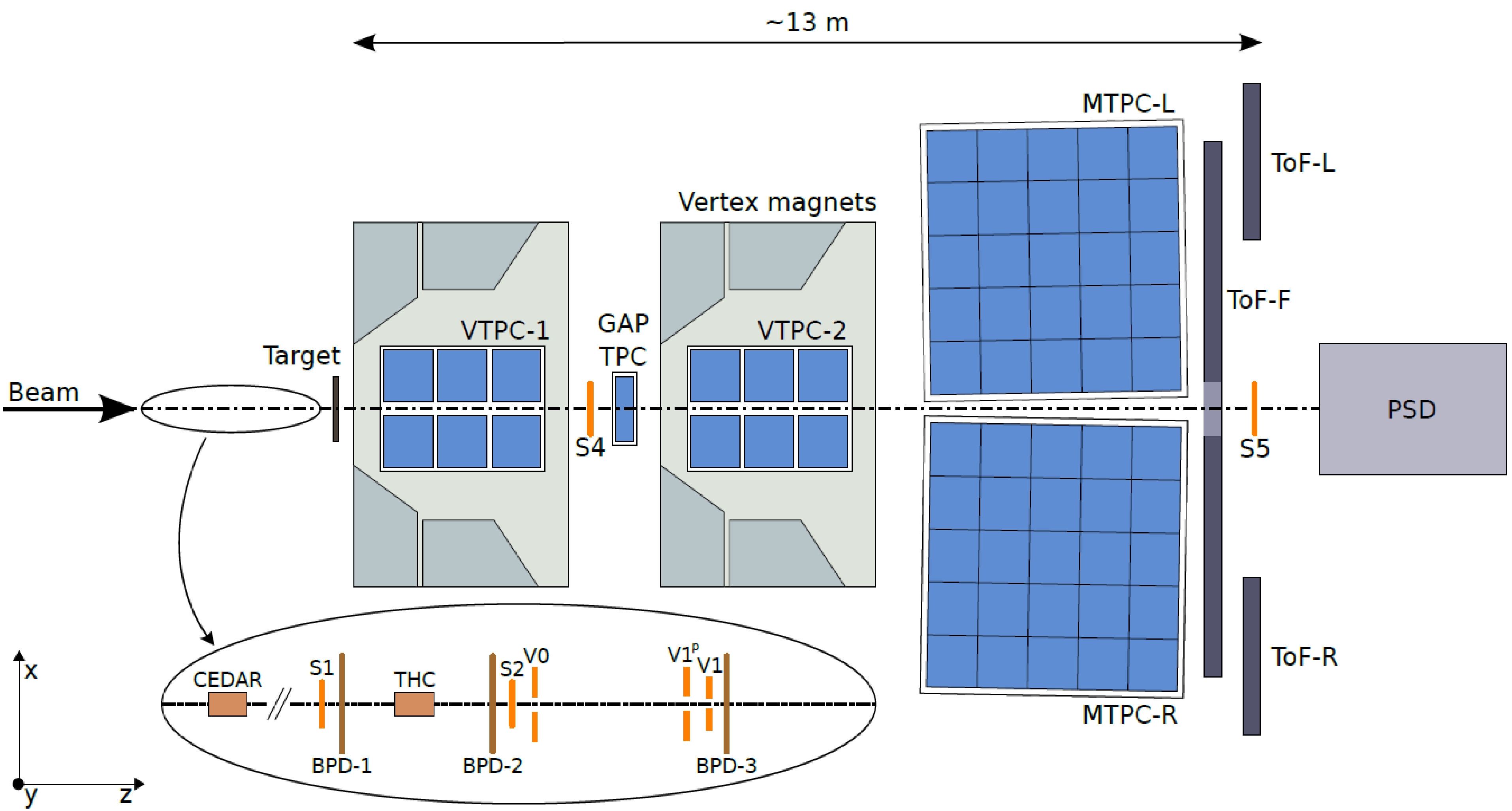
Towards the ideal detector

The ideal detector for fluctuations:

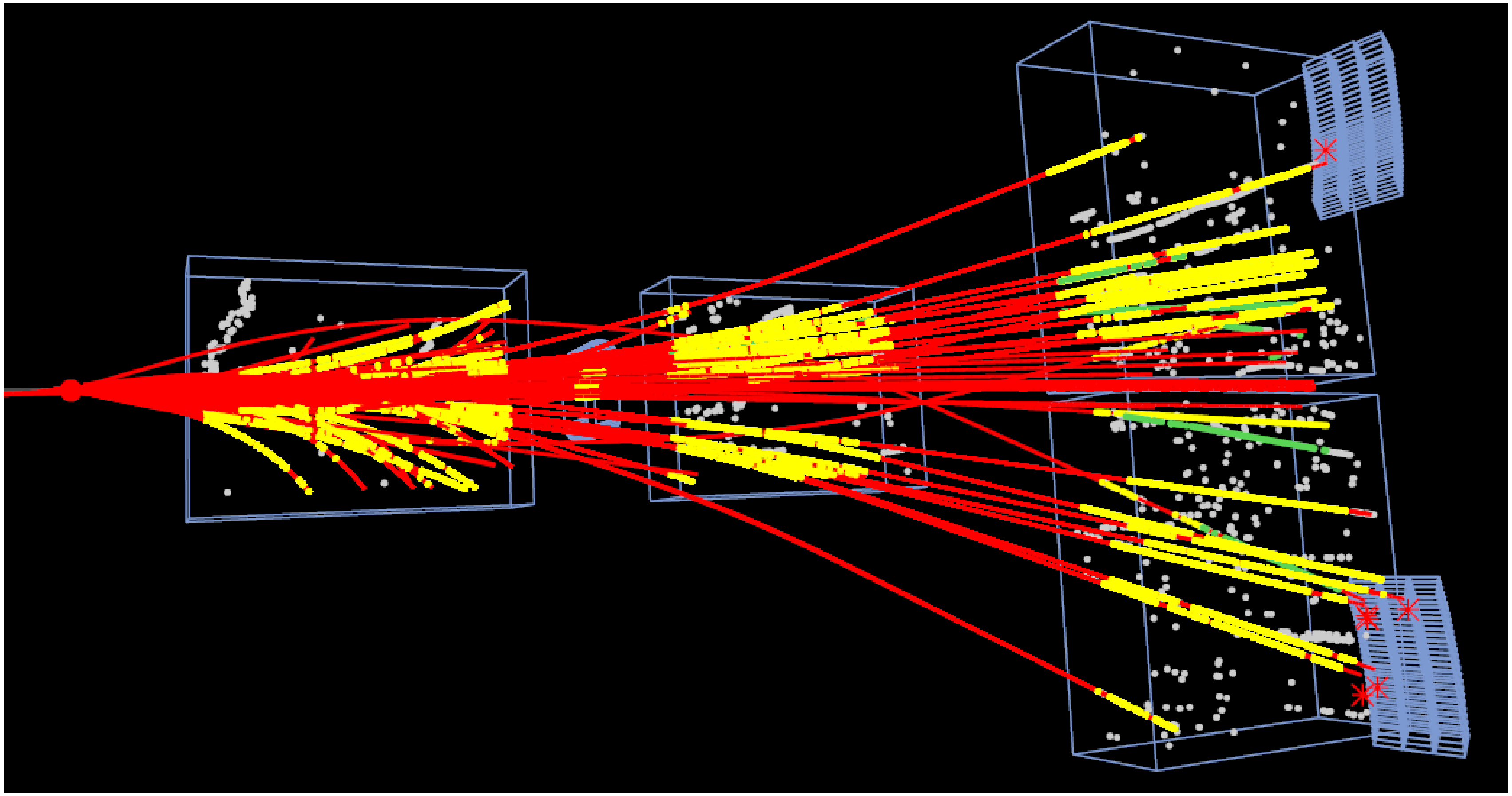
- has almost full acceptance (more than 90% of all charged pions are measured),
- is massless (less than 1% of tracks come from secondary interactions) and
- may be slow (bulk event properties are of interest).

Clearly ideal detectors for fixed target and collider experiments will differ:
- in the back-up ideas on an ideal detector for the low energy collider, NICA,
- next several slides are on an ideal detector for a very high energy fixed target experiment @ LHC

The NA61/SHINE: 50% of the ideal experiment:



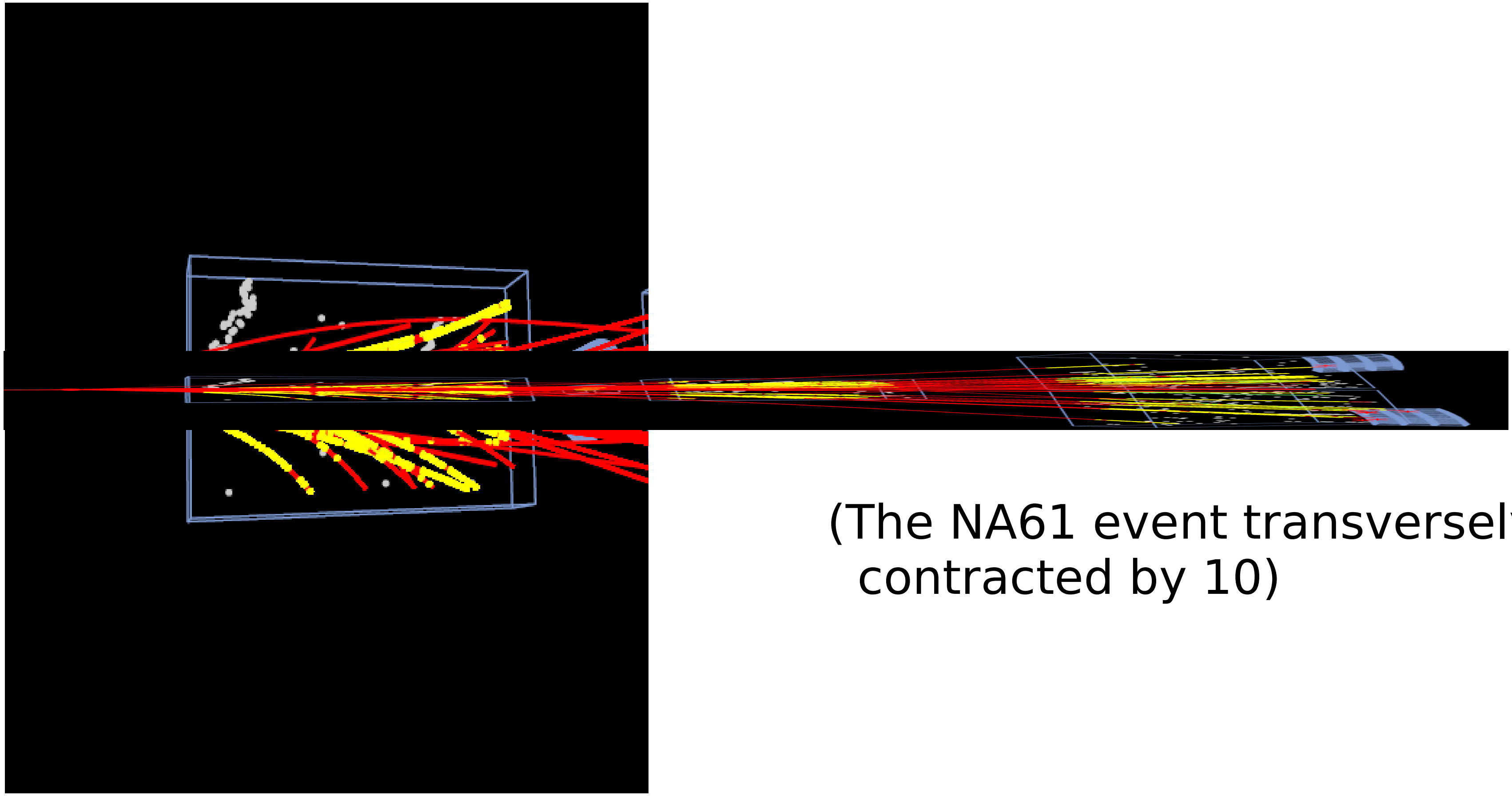
NA61: Be+Be collision at 150*A* GeV/c



<N>/<W> ≈ 5 → central Pb+Pb: 1000 tracks
(Detector: TPC-based, Bl = 9 Tm, two track resolution about 1 cm, point resolution about 0.05 cm)

AFTER-F: Be+Be collision at 1500*A* GeV/c

(AFTER-F = A Fixed Target Experiment - Fluctuations at LHC)



(The NA61 event transversely contracted by 10)

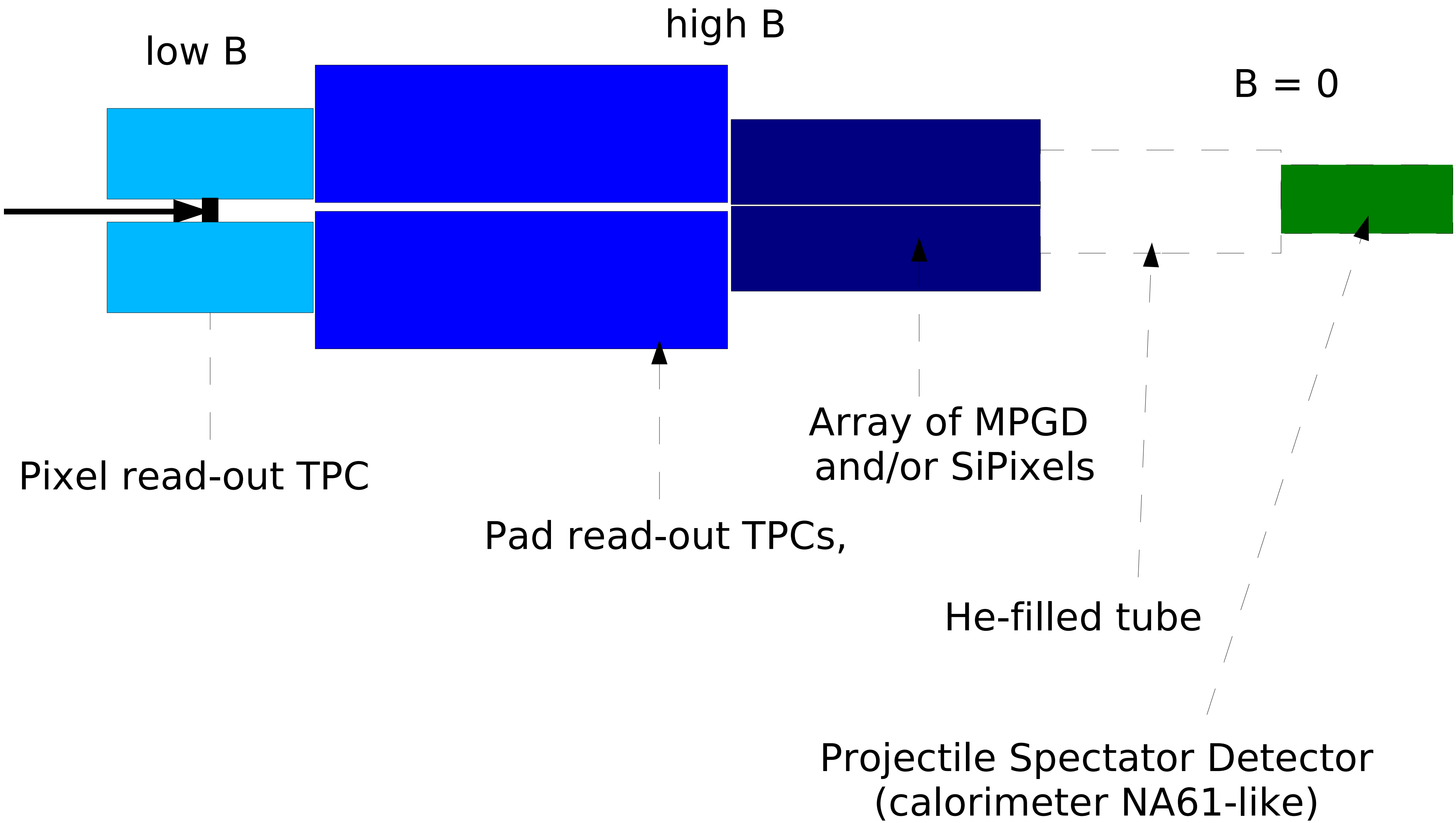
<N>/<W> ≈ 10 → central Pb+Pb: 2000 tracks
→ similar to NA61 multiplicities, but significantly higher particle longitudinal momenta and thus a strong forward focusing

Therefore, in the forward region one needs:
- higher Bl (> 9 Tm),
- better two-track resolution (< 1 cm),
- better point resolution (< 0.05 cm)

→ AFTER-F cannot be based on the NA61-like TPCs, in the forward region one may consider micro-pattern gas detectors and/or silicon pixel detectors and, in the target, region a TPC with the GEM pixel read-out

The AFTER-F detector: the first ideas

Top view, not to scale, blue boxes in the vertical dipole B field



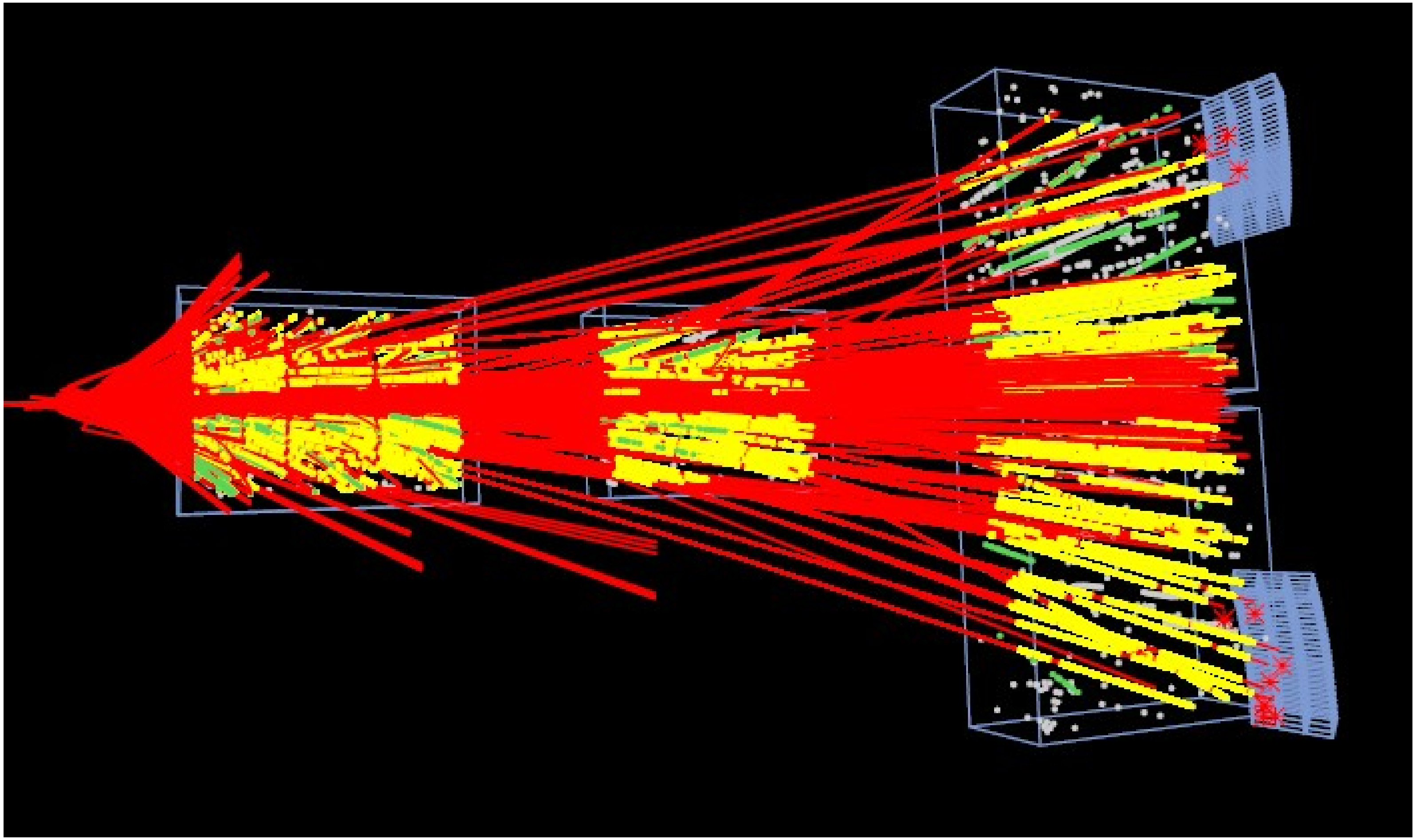
Conclusions:

Furture of heavy ion collisions:
→ Fluctuations:
→ FT@LHC

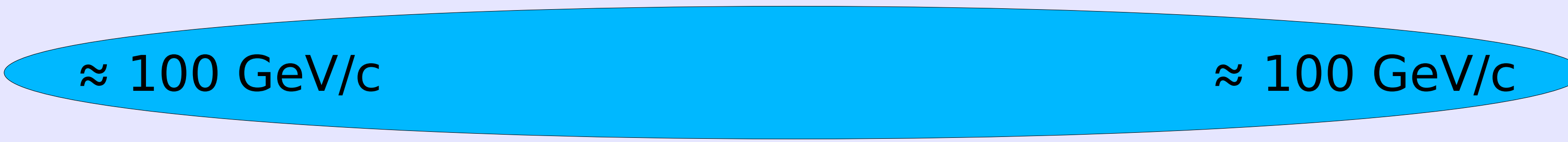
What we need is a fixed target area at the LHC which could host at least two experiments optimized for different measurements:
- di-muon spectra
- event-by-event fluctuations.

Additional slides on an ideal detector for an experiment at NICA

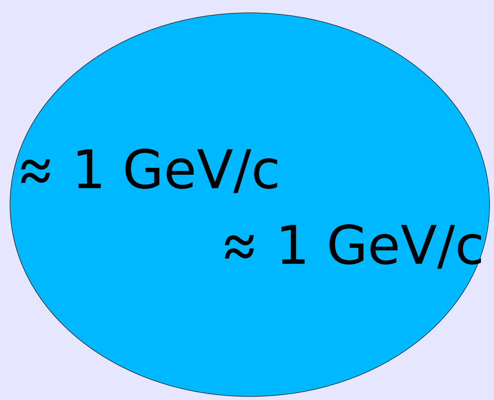
NA61: Pb+Pb collision at 80*A* GeV/c



The current detector at NICA design resembles closely the set-up of STAR and ALICE detectors. They are determined by the topology of very high energy nucleus-nucleus collisions, namely the majority of hadrons is emitted in two narrow and dense forward-backward jets with a typical hadron momentum of about 100 GeV/c:



The topology of a typical low energy nucleus-nucleus collision at NICA is very different. The hadron distribution is significantly more isotropic, particle multiplicity and density are moderate and typical momenta are only about 1 GeV/c



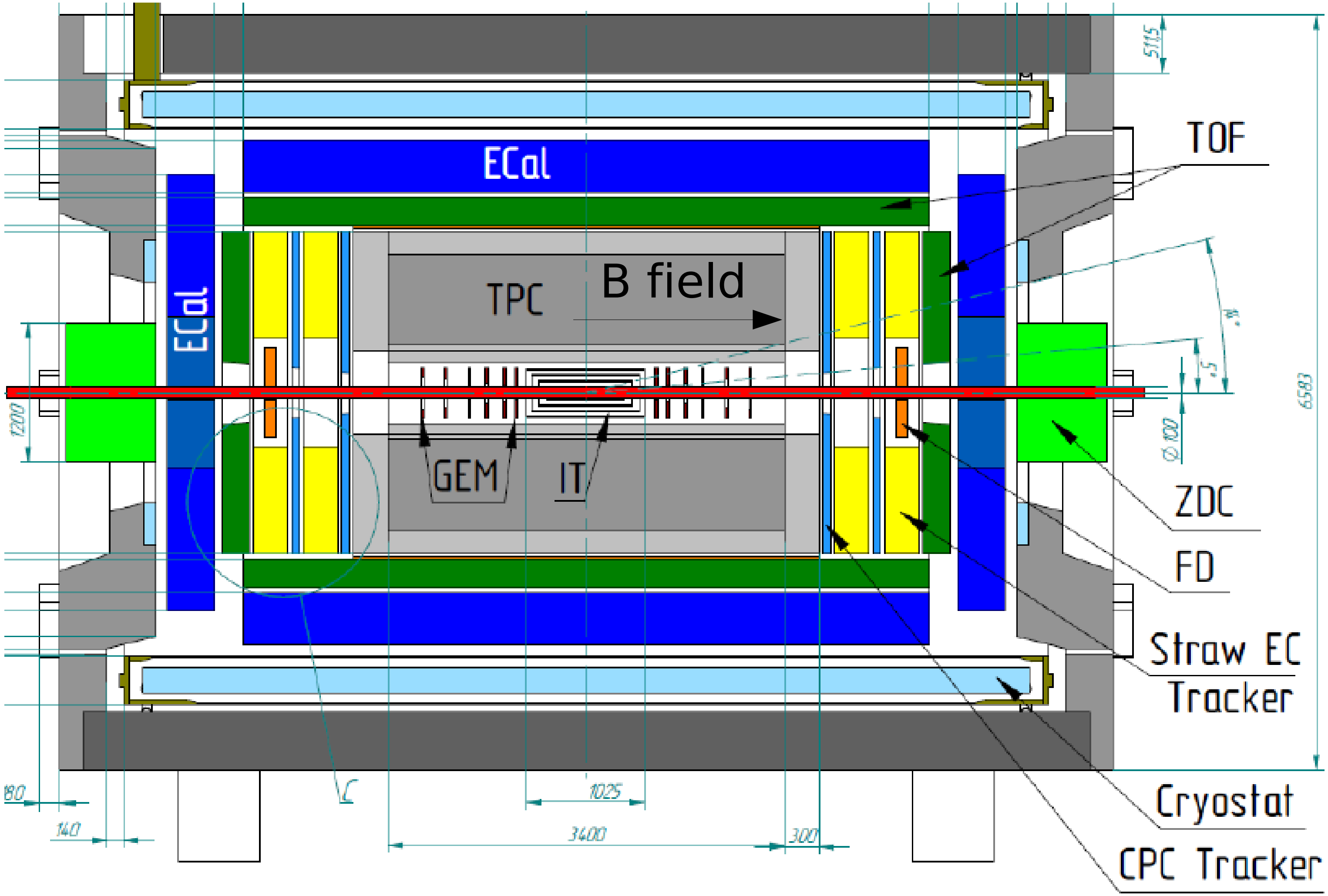
This suggests that the optimal set-up for a detector at NICA may be different than the ALICE and STAR ones.

Due to the topology of very high energy events and physics goals the ALICE and STAR TPCs are cylindrical with the inner cylinder being not instrumented.
The magnetic field is along the beam direction.

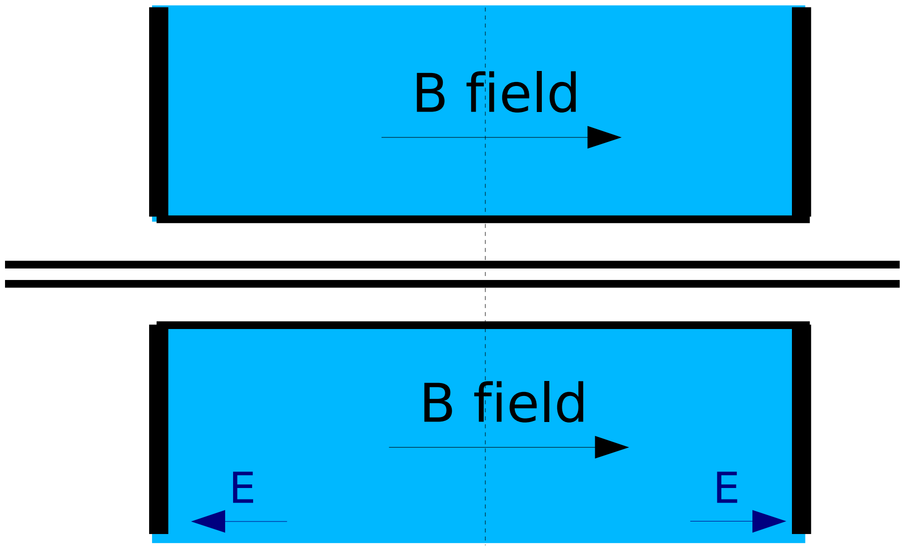
This allows to measure transverse momentum spectra at mid-rapidity in the medium and high p_T domains, as well as correlations in p_T and azimuthal angle in the acceptance.

At the low collision energies, the event topology and particle multiplicity allow to measure particle production in a broad acceptance in the fixed target experiments, e.g., NA49 and NA61/SHINE.
The magnetic field is perpendicular to the beam direction.
This configuration should lead even to a better acceptance in the case of collider experiments.

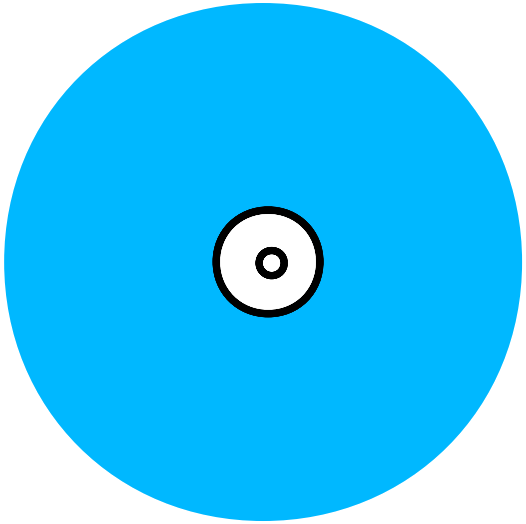
The ALICE-like MPD detector for NICA:



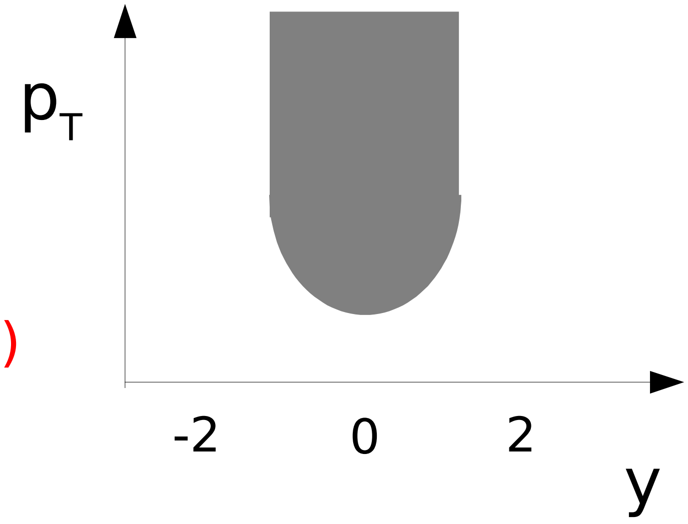
The ALICE-like solution:



central TPC



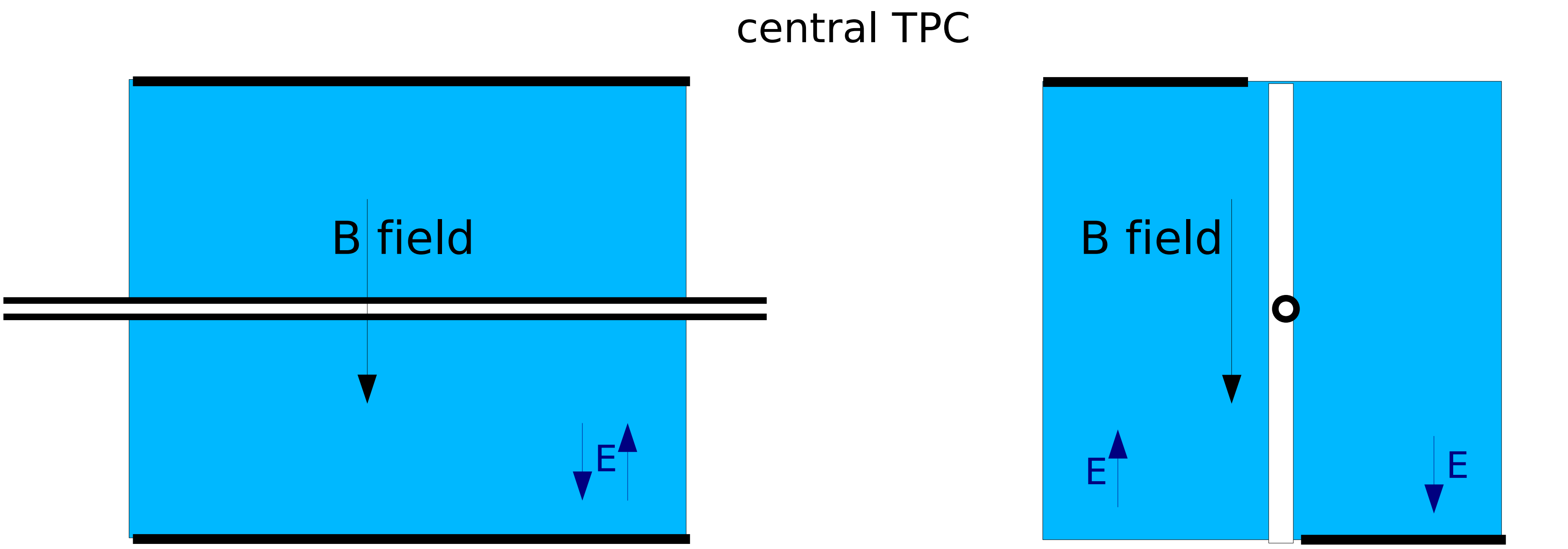
TPC acceptance



Advantage:
- rotational symmetry

Disadvantages:
- significantly limited y-p_T acceptance,
- material in the TPC acceptance (inner walls) and in the acceptance of side detectors (TPC read-out, end caps)

The 2xNA61-like solution (single diople or two dioples (SFM):

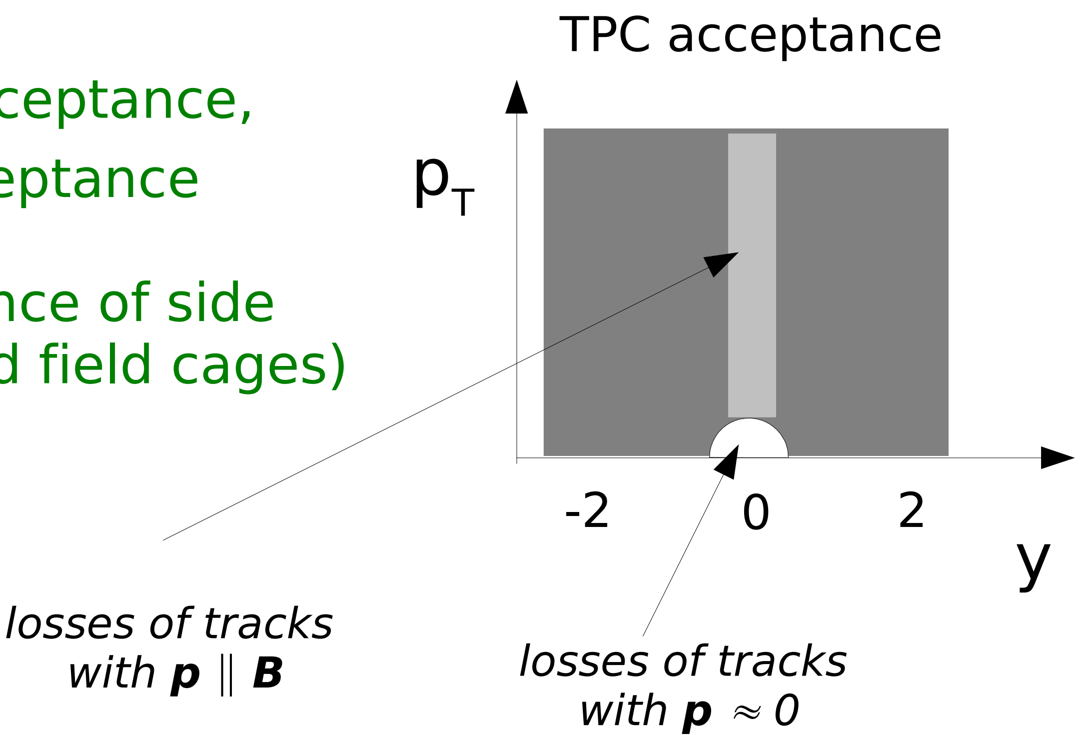


Advantages:

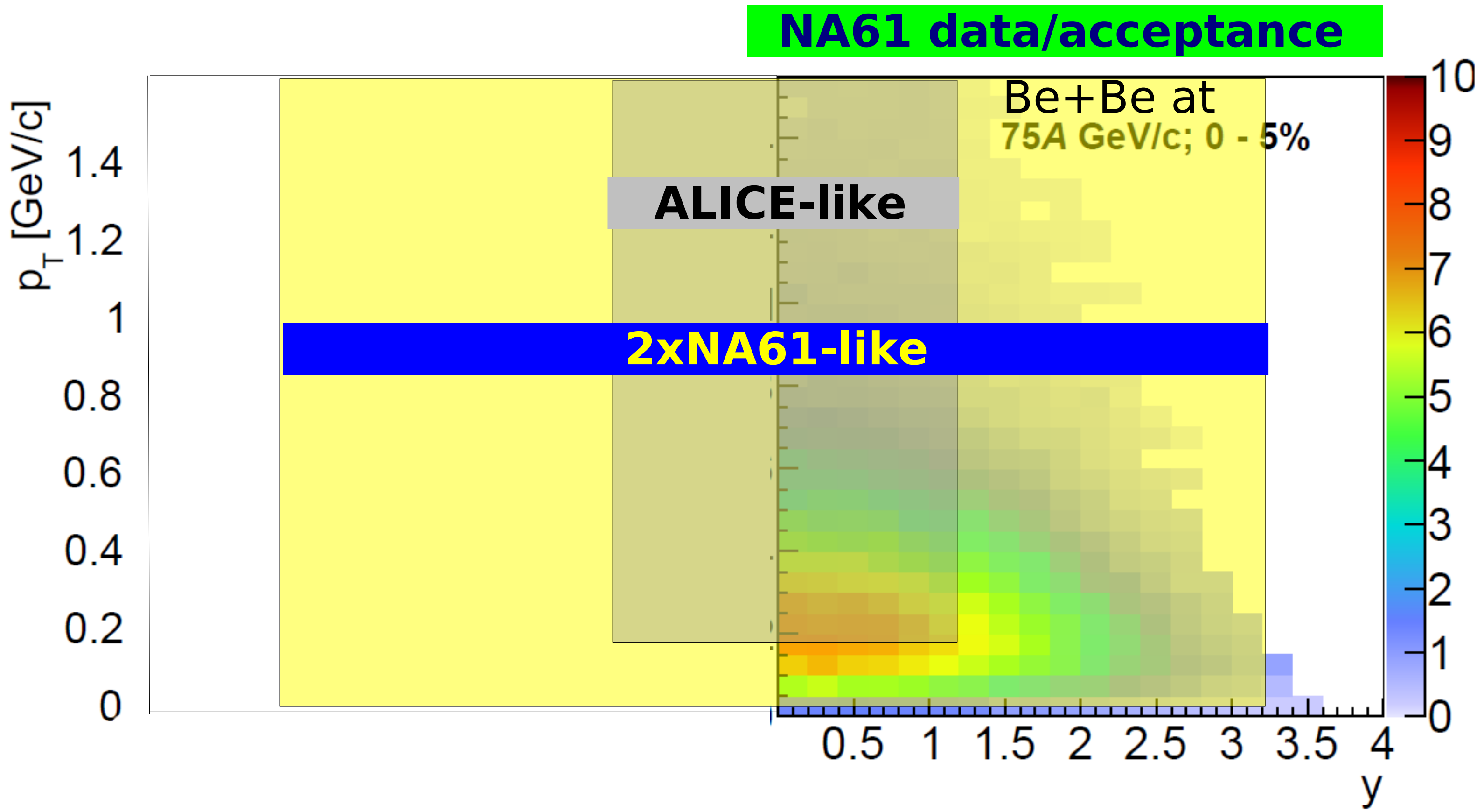
- probably almost complete y-p_T acceptance,
- minimum material in the TPC acceptance (beam pipe only)
- minimum material in the acceptance of side detectors (only foils of the gas and field cages)

Disadvantage:

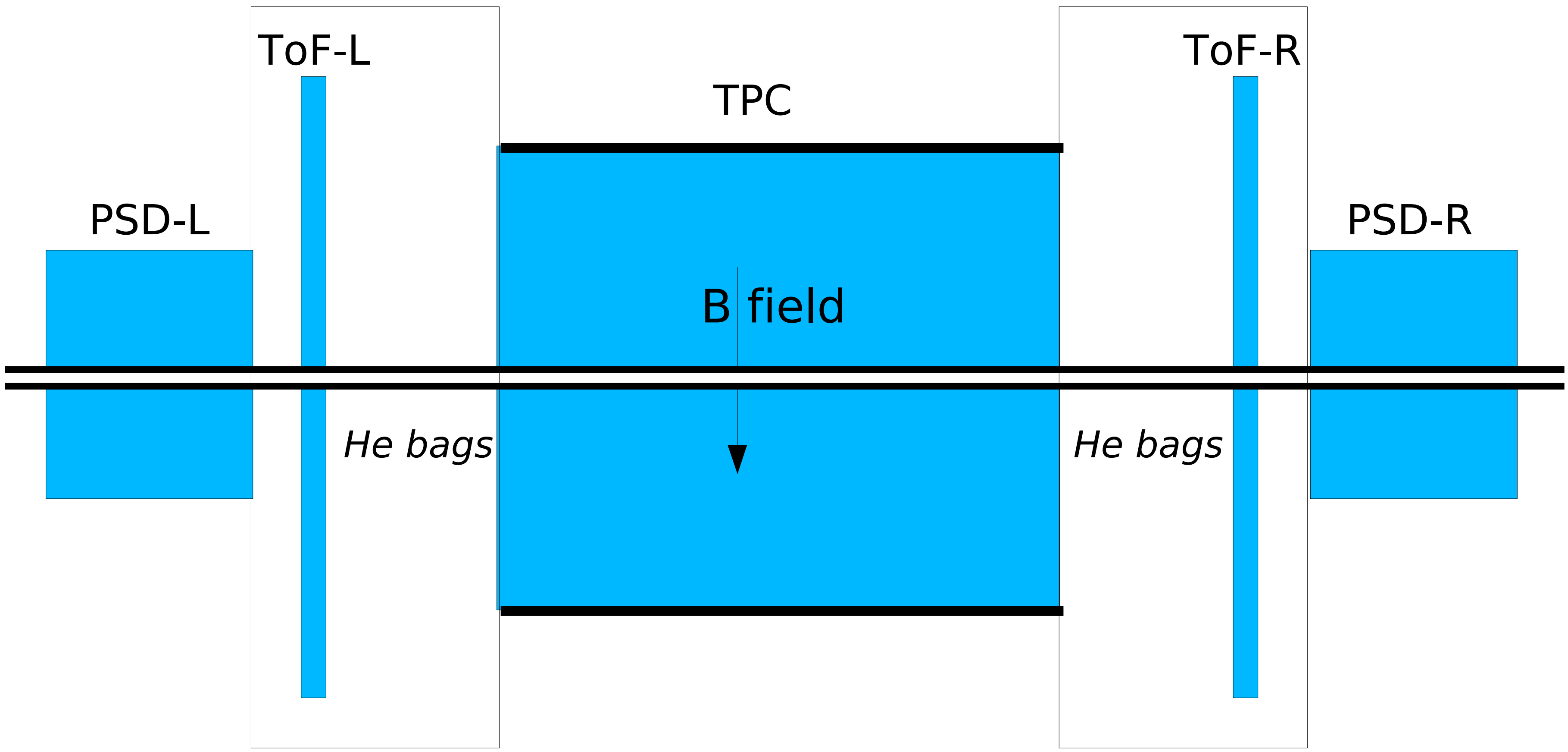
- no rotational symmetry



Schematic comparison of TPC acceptances for charged pions at about 11 GeV:



The 2xNA61-like detector for NICA:



.., probably closer to the ideal detector than ALICE-like one but it is still not perfect (non-uniform acceptance in azimuthal angle, collider beams in the (strong) magnetic field, ...)

Thus your help is needed !